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Latitudinal variation of OI 6300 Å line intensity reviewed in the light of Barbier's equation

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Abstract Latitudinal variation of OI 6300 Å line intensity has been computed and a least square fitted curve has been obtained for the same OI 6300 Å line-intensity, as observed at Narendrapur (Lat 22°35' N, long 88°21' E) during the period 1984-1986 has been compared with the values of the same quantity obtained from empirical relation as given in Barbier's equation (*J Geophys Res* 68 5605 (1963)) [7] using ionospheric parameters h'F and f_oF_2 at Ahmedabad (Lat 23°01' N, long 72°36' E) for the same period The correlation coefficient between them has been calculated and is found to be of sufficiently high values An empirical equation relating the two above mentioned variables has been established Similarly using the ionospheric parameters f_oF_2 and h'F of Kodaikanal (Lat 10°44' N, long 77°29' E) station the corresponding OI 6300 Å line intensity for each month for the period 1984-1986 has been computed using the Barbier's empirical relation This curve is again compared with the corresponding values of the same parameter obtained separately from the latitudinal variation-fitting equation and the corresponding values of OI 6300 Å line intensity at Narendrapur Except at a few portions both the curves has been found to compare well with each other. Lastly as a possible cause of such variation of OI 6300 Å line intensity the similar variation of electron density has been referred

Keywords OI 6300 Å line intensity, ionospheric parameters, latitudinal variation

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1. Introduction

Photometric observations of the night airglow made aboard USNS Eltanin were reported in details by Davis and Smith [1] In this report, the authors along with other observations on various airglow lines revealed out some specific features and a general nature of latitudinal variation of OI 6300 Å line intensity. The latitude *versus* OI 6300 Å line intensity graph was drawn after taking the 10° latitude-running average values of OI 6300 Å line intensity for the purpose of finding out the actual latitude-variation of line intensity of that line. Latitudinal variations of OI 6300 Å line intensity of night airglow has also been considered and analysed by Chandra *et al* [2]. In their work, Chandra *et al* considered observations from satellite Ogo 4 which revealed global pattern of variations of OI 6300 Å line intensity. It was observed that post sunset emission of OI 6300 Å was asymmetrically distributed with respect to the geomagnetic equator and this was associated with the similar asymmetry in the variation of electron density at the peak of the F_2 layer. Chandra *et al* reported also that the variation of OI 6300 Å line intensity showed poor correlation with electron density measured simultaneously. Unlike the work of Davis and Smith, in the work of Chandra *et al* the latitudinal-variation of oxygen red line intensity had not been demodulated from the complex combination of a number of factors such as altitude, longitude *etc.* coupled with the latitude and therefore their work lacks a pure latitudinal variation of OI 6300 Å line-intensity. Hence the authors have considered the raw data form the paper of Davis and Smith in this paper. Besides these, there are several other works on latitudinal variations of airglow

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line intensities [3,4] in which the authors have discussed behaviour of intensities of various airglow lines similar to those mentioned above.

Davis and Smith-curve for latitudinal variation of OI 6300 Å line intensity has been fitted with a formula showing nature of variation of the oxygen red line intensity on various factors of significance.

Photometric observations were taken at Narendrapur for at least twelve nights each month of the period 1984–1986 and for each night approximately eight hourly (mostly from 20 IST to 4 IST) observation were taken. These observed values of OI 6300 Å line intensity at Narendrapur has been compared with corresponding Barbier-equation modelled values for same months of the period 1984-1986 at Ahmedabad. A regression equation [eq. (2)] relating the observed and modelled values has been established which is described later in the text. Putting the Barbier-equation-modelled values of oxygen red line intensity for Kodaikanal station into the above mentioned regression equation [eq. (1)] the expected values of OI 6300 Å line intensity has been found out. On the other way round the expected values of the same physical variables for the same period at the very same station Kodaikanal has been calculated by putting the corresponding observed values of OI 6300 Å intensities at Narendrapur station into the latitudinal variation-modelled equation [eq. (2)] given later in the text. Then those two values are compared. Moreover contrary to the conclusion made by Chandra *et al*, it has been shown also here that the oxygen red line intensity varies more or less perfectly according to the variation of electron density in F-region.

2. Data generation, interpolation, analysis and result

In this paper raw data has been derived from the 10° latitude averaged OI 6300 Å line intensity profile against latitude of Davis and Smith [1] and the graph has been redrawn relatively smoothly (Figure 1). A mathematical formula that fits well with the observed values has been found out by

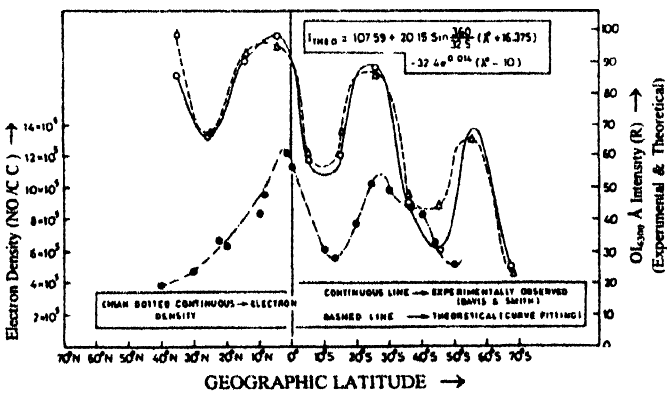

Figure 1. Variation of OI 6300 Å nightglow emission, both observed [1] and curve-fit values, and observed electron density [9] against geographic latitude.

applying method of collocation and then by successive approximation. Method of collocation refers to an approximate way of specifying the nature of variation from graphical plot of actually observed data in which an almost accurate combinations of variables are arranged in the form of an equation so as to match with the observed profile to a large extent. This method may contain several steps depending on the number and complexiety of functions that suit the given profile. Successive approximation means a step by step gradual modification of values of all constant coefficients associated with variables or a constant phase part so as to reach a perfection to the maximum possible extent. The Davis-Smith curve fitting formula obtained as

$$I_{6300(\mathrm{theo})}(R) = 107.59 + 20.15\ \sin[(360/32.50) \times \{\lambda^\circ + 16.375\}] - 32.4 \times \exp\{0.014\lambda^\circ - 0.14\}, \quad (1)$$

where, λ° is the geographic latitude expressed in degree is considered negative for north and positive for south. This particular sign-convention is actually required for establishing the latitude variation modelling equation [eq. (2)] directly from Davis-Smith curve where northern latitude has been shown on the left and southern on the right panel of the graphical plot. Similar convention had been adopted by Chandra *et al* [2] too. The accuracy of this formula is adjudged by finding the correlation coefficient between the observed values and theoretical values of $I_{6300}(R)$ using eq. (1) which has been as high as 0.97 with standard error value 0.02 and this confirms that the equation (1) is very accurate in giving the exact latitude-variation profile (Figure 1) of $I_{6300}(R)$ of night airglow. This equation has two distinctly different modes of variation with latitude, namely the continuous with a very slowly varying function of latitude and the oscillatory with an appreciably high amplitude. The first part *i.e* the non-oscillatory part is

$$I_{6300(\mathrm{theo})}(R)_{\mathrm{N.O.}} = 107.59 - 32.4\ \exp\{0.014\lambda^\circ - 0.14\}$$

which may be regarded as the means of biasing up the oscillatory part as given by

$$I_{6300(\mathrm{theo})}(R)_o = 20.15\ \sin[(360/32.5)\{\lambda^\circ + 16.375\}].$$

The oscillatory part has an average period of oscillation 32°.5 and an epoch of 16°.375. Geomagnetic latitude is approximately 10° to 15° ahead of geographic latitude and that confirms an almost perfectly symmetric distribution of oscillatory part of $I_{6300(\mathrm{thro})}(R)$ about geomagnetic equator. This most important oscillatory part may be accounted for by the specific pattern of variation of geomagnetic field intensity with geomagnetic latitude while the non-oscillatory part may be attributed to the general global pattern of wind speed distribution with respect to the latitude. Monthly mean values of observed intensity of OI 6300 Å nightglow at Narendrapur (Lat. 22°35' N, long 88°2' E) near Calcutta has been plotted (Figure 2) against the corresponding months

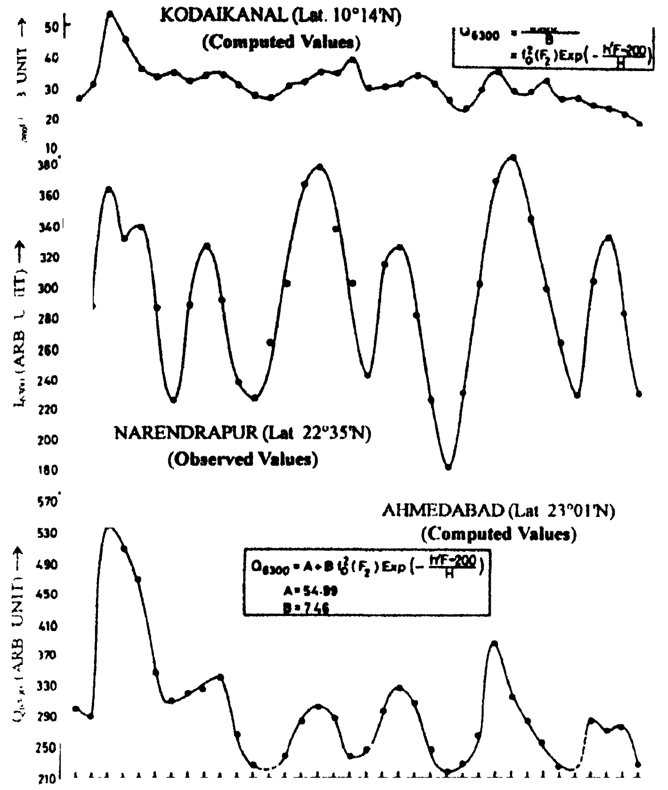

Figure 2. Comparison of experimentally observed, monthly mean values of OI 6300 Å nightglow intensity at Narendrapur with Barbier's equation-computed similar values of OI 6300 Å nightglow at Ahmedabad and Kodaikanal, plotted against month for the period of 1984–1986

for the period 1984-1986, the descending phase of 21[st] solar minimum. The experimental arrangement has been described in details in other papers of the authors already published [5,6]. In absence of simultaneous ionospheric data at Calcutta the data of $h'F$ and f_oF_2 at Ahmedabad (Lat. 23°O' N, long 75°36'E) which latitudinally is very very close to and longitudinally not very far apart from Narendrapur, has been collected from Ionospheric Data Book, published by National Physical Laboratory, New Delhi. Putting those data into Barbier's equation and considering the scale height of oxygen the same as was used by Barbier [7] himself a number of equations involving constant terms of Barbier's equation are obtained. Then choosing suitable pairs of such equations and equating them with the corresponding OI 6300 Å intensity observed at Narendrapur for exactly the same period as that of the ionospheric data at Ahmedabad considered the equations were solved for Barbier constants. From a number of close values of each constant derived that way, the average of each constant was found out and were used. The Barbier-equation computed values of OI 6300 Å was plotted against months for the same period 1984–1986 and was compared with the observed values of Narendrapur station (Figure 2). A good correlation was obtained with correlation coefficient equal to 0.6 along with a standard error value equals to 0.1. The 95% confidence limit for the correlation coefficient is found to be 0.32 to 0.79. A regression equation has been found by applying least square method of curve fitting (Figure 3) and the equation is given below :

$$I_{6300} = 0.738Q_{6300} + 83.121, \quad (2)$$

where, Q_{6300} is the Barbier-equation computed value of oxygen red line intensity and I_{6300} is the experimentally observed value of the same. As these observed values were collected in terms of photocurrent through a nanometer and used without converting into the unit of Rayleigh, these have been plotted in terms of an arbitrary unit proportional to the photocurrent.

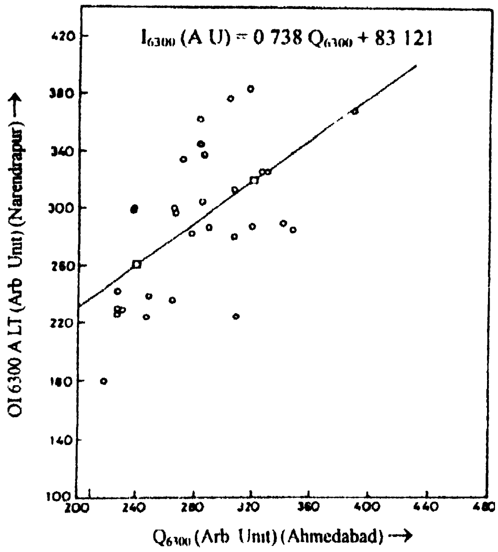

Figure 3. Regression curve between Narendrapur-observed values and Ahmedabad-Barbier's equation-computed values OI 6300 Å nightglow intensity (monthly mean)

Now, the Q_{6300} value at Kodaikanal for the same period 1984–1986 has been obtained from ionospheric and magnetic section, Kodaikanal Institution of Astrophysics, Kodaikanal, India. These data have been plotted against months of that period (Figure 2). Again I_{6300} value at Kodaikanal has been obtained using eq. (2) and the values of Q_{6300} of that station. These I_{6300} values of Kodaikanal station has been plotted against months for the period 1984–1986 (Figure 4). Then the similar values of OI 6300 Å line in tensity for Kodaikanal station for each month of the same period has been obtained from the following equation and the values of corresponding variables on the right side of the equation :

$$I_{6300}(\text{Kodaikanal}) = \frac{I_{6300}(\text{Narendrapur})}{I_{6300(\text{theo.})}(\lambda)(\text{Narendrapur})} \times I_{6300(\text{theo})}(\lambda)(\text{Kodaikanal}) \quad (3)$$

Assuming the ratio of the observed and latitude fitting equation (Figure 1) based values of OI 6300 Å at Narendrapur to be a constant scale factor and multiplying with that factor the corresponding latitude-fitting-formula-based values of oxygen red line intensity at Kodaikanal, the value of the same parameter at Kodaikanal, speculated to be observed if instrument were set properly to observe it, has been obtained theoretically.

The value of $I_{6300(\text{theo})}$ (λ) (Kodaikanal) *i.e.* the OI 6300 Å airglow intensity value for Kodaikanal station calculated from eqs. (1) and (3) along with the observed value of OI 6300 Å line intensity at Narendrapur for all months of the period 1984-1986 has been plotted on the graph (Figure 4). Then the Barbier equation-modelled values of OI 6300 Å line intensity (Q_{6300}) for all months of the very same period as above has been calculated from ionospheric data of Kodaikanal station for that period and after transforming it to speculated observable values using eq. (2) have been plotted on the same graph (Figure 4). It is then observed

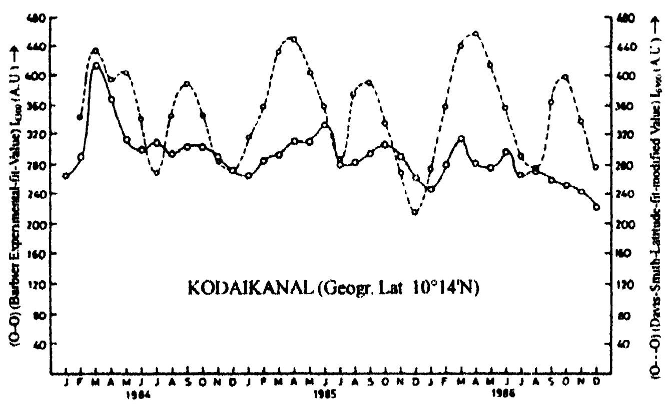

Figure 4. Comparison between Davis-Smith-latitude-fit modified value and Barbier Experimental-fit-value of OI 6300 Å nightglow intensity at Kodaikanal, plotted against month for the period 1984–1986

that except at à few region of mismatch the inclines and declines of the two curves occur more or less consistently with each other. This undoubtedly confirms the proper validity of the general nature of latitude variation of OI 6300 Å from eq. (1).

Duncan [8] calculated F-region electron content per vertical column for different latitudes which showed striking similarity with the variation of OI 6300 Å nightglow intensity specially for low latitude area. But for high latitude sector, latitudinal variations of electron density and oxygen red line intensity of night airglow are opposite in nature which according to Shepherd [4], is due to the plasmapause effect. Wu and Newill [9] matched data of ionospheric electron content and the corresponding variation of computer simulated data with latitude was presented by them for the months of June and December, 1963. We have taken the mean of these two seasons for each latitude and have drawn a latitudinal variation of total electron content (TEC) curve on the same figure (Figure 1) as that of Davis-Smith curve. It is observed that almost a similar pattern of variation with respect to latitude has been obtained and thereby reaffirm the observations of the other investigators mentioned immediately earlier. Now, how $I_{6300Å}$ and TEC are correlated along with the significance of considering TEC here, can be understood from the following discussion. Amongst the many possibilities, the following are the causes of most significant contributions towards the production of forbidden oxygen red line emission.

Singly ionised atomic oxygen O^+ interacts with different molecules to produce corresponding ions :

$$\left.\begin{array}{l} O^+O_2 \longrightarrow O_2^+O, \\ O^+ + N_2 \longrightarrow NO^+ + N. \end{array}\right] \quad \text{(i)}$$

Now, O_2^+ may be lost mainly in the following two ways

$$\left.\begin{array}{l} O_2^+ + N \longrightarrow NO^+ + O, \\ O_2^+ + e \longrightarrow O^* + O^*. \end{array}\right] \quad \text{(ii)}$$

$$NO^+ + e \longrightarrow N + O^*. \quad \text{(iii)}$$

O^* produced in the above way are either in ^1S or in ^1D state, which jumping over to states $^3P_1$ and $^3P_2$ produces oxygen red doublets [10].

O^* produced due to reaction (iii), does not necessarily give rise to such excited states as mentioned, because of spin conservation [11]. $O(^1D)$s are also lost mainly in the following two ways :

$$\left.\begin{array}{l} O(^1D) + N_2 \longrightarrow O(^3P) + N_2, \\ O(^1D) + e \text{ (slow electron)} \longrightarrow O(^3P) + e. \end{array}\right] \quad \text{(iv)}$$

Of course the loss due to the second part of reactions (iv) may be counter balanced by additional impact excitation such as,

$$O(^3P) + e\ (\delta \geq 10 \text{ eV}) \longrightarrow O(^1D) + e.$$

Ionisation rate is closely associated with the production of electron which in turn relate to TEC and through N_mF_2 it gives rise to the OI 6300 Å nightglow intensity. Other authors like Huruhata *et al* [12] and Salaria *et al* [13], Mukherjee and Carlo [14] have shown that the nightglow enhancements are associated with nighttime enhancement in TEC (Total Electron Content). They have used the time rate of change of content to obtain rough estimate of the nightglow intensity level which shows an acceptable level of agreement with the values of the same parameter predicted by MSIS 86 (Hedin [15] and FAIM [16]), models. Again as Unnikrishnan *et al* [17] observed that the average TEC response for the nighttime storms are predominantly positive for low latitude station and negative for the mid and high latitude stations. Using SUPIM, Su *et al* [18] have found that the value of N_mF_2 can be stronger or weaker depending on the competition between the effects of increased chemical loss rate and the downward flow of plasma from the plasmasphere by the stronger poleward wind. At night, the stronger crests in both TEC and N_mF_2 occur in the hemisphere of stronger equatorward wind. They also show that latitudinal distribution of ionisation at low latitude is characterized by a trough at the dip equator with crest about ±17° dip latitude. Nightglow intensity of OI 6300 Å line have crests at about ±17° geomagnetic latitude sectors on both hemispheres (Figure 1). Now an approximate theoretical explanation of this behaviour is given below.

Bates [19] mentions that $\varepsilon(^1D)$ being the effective number of $O(^1D)$ atoms produced per O_2^+ recombination (directly or by cascading) the volume emission rate of the more prominent member of the forbidden doublet is given by

$$Q(6300) = \int_{100\ \mathrm{km}}^{600\ \mathrm{km}} \frac{A(6300)n(e)n(O_2^+)\alpha_5\delta(^1D)dh}{A(6300+6364)+\beta_7 n(N_2)+\beta_8 n(e)}, \quad (4)$$

where $A(6300 + 6364)$ is the transition coefficient for the doublet, $A(6300)$ is the transition coefficient of the prominent member of the doublet, ε_i's and β_i's are the rate coefficients.

In cases where density $n(O_2)$ cannot be measured, an alternate formula of wider applicability may be given as,

$$Q(6300) = \int_{100\ \mathrm{km}}^{600\ \mathrm{km}} \frac{A(6300)n(e)n(O_2)\beta_2\delta(^1D)dh}{A(6300+6364)+\beta_7 n(N_2)+\beta_8 n(e)(1+C)(1+B)}, \quad (5)$$

where $C = \dfrac{n(N)\beta_4}{n(e)\alpha_5}$.

B is the fraction of molecules that are molecular *i.e.*

$$B = B_1 + B_2$$

while $B_1 = n(O_2)\beta_2 n(e)(1 + C)$.

$$B_2 = [n(N)B_1\beta_4 + n(N_2)\beta_3]/n(e)\alpha_6$$

$$n(N)/n(O) \approx 0.01 \text{ near 250 km.}$$

C' is implicitly assumed to be equal to zero. Above 250 km, B may be neglected compared to unity. Then, eq. (5) becomes

$$Q(6300) = \int_{100\ \mathrm{km}}^{600\ \mathrm{km}} \frac{A(6300)n(e)n(O_2)\beta_2\delta(^1D)dh}{A(6300+6364)+\beta_7 n(N_2)+\beta_8 n(e)}. \quad (6)$$

Height of peak emission of OI 6300 Å airglow line lies between 200 kms to 300 kms where the average temperature may be considered to be around 800 K. Maurice and Torr [20] gives

$$\beta_2 = [2.82 \times 10^{-11} - 7.74 \times 10^{-12}(T/300) + 1.73 \times 10^{-12}(T/300)^2 - 5.17 \times 10^{-14} \times (T/300)^3 + 9.65 \times 10^{-16}(T/300)^4]\ \mathrm{cm^3\,s^{-1}}.$$

Putting the value of average temperature mentioned above, the value of β_2 is found to be

$$\beta_2 = 1.423 \times 10^{-11}\ \mathrm{cm^3\,s^{-1}}.$$

Mul and McGowan [21] have proved that the value of β_7 as was obtained from the observation from Atmospheric Nightglow Data Explorer, is given by

$$\beta_7 = 2.3 \times 10^{-11}\ \mathrm{cm^3\,s^{-1}}.$$

Berrington and Burke [22] have determined the value of deactivation rate coefficient for metastable OI as

$$\beta_8$$

for the average temperature as mentioned above. Link and Cogger [23] took the value

$$\beta_8 = 6.2 \times 10^{-10}\ \mathrm{cm^3\,s^{-1}}$$

which is almost the same as above. Following the prescription of Walls and Dunn [24], we have taken

$$\varepsilon\,(^1D) = 1.3$$

which was also considered by Link *et al* [25].

The value of $A(6300)$ and $A(6300+6364)$ has been taken to be as follows :

$$A(6300) = 5.15 \times 10^{-3}/\mathrm{sec},$$

$$A(6300 + 6364) = 6.81 \times 10^{-3}/\mathrm{sec}.$$

These values were taken from the woks of Link and Cogger [23] and Kernahan and Pang [26] respectively.

Following Bates's prescription [13]

$$n(O_2)/n(N_2) = 0.05$$

and $n(N_2) = 5.2 \times 10^8$

and then putting this value of $n(N_2)$ for the peak emission height of OI 6300 Å airglow line, we can write

$$n(O_2) = 2.6 \times 10^7\ \mathrm{cm^{-3}}.$$

Putting these values of the corresponding parameters in eq. (6) and neglecting relatively very smaller values associated, we can finally write

$$Q(6300) = \frac{n(O_2)n(e)}{18.38n(O_2)+2.73} \simeq \frac{n(e)}{18.38}.$$

In this way, it is found that the OI 6300 Å airglow intensity is approximately proportional to the number density of free electron in the peak-emission layer for OI 6300 Å line intensity. Streit *et al* [27], while investigating the temperature-dependence of deactivation rate constant for $O(^1D)$ by quenching molecules like N_2, CO_2, O_3 through Arhenius parameters find that N_2, CO_2, O_3 have a negative temperature-dependence. Hedin [15] mentions that temperature of thermosphere depends on latitude although there is no particular equation giving the nature of variation of temperature with latitude. Thus combining Hedin's observation with Streit *et al*'s observation mentioned above quenching rate may be said to depend on latitude and thus OI 6300 Å line emission intensity depends on latitude too.

3. Discussion

Schunk [28] in his detail discussion on features of the terrestrial ionosphere mentions that terrestrial ionosphereic variations, with latitude, altitude *etc.* are consequences of balancing and disbalancing specially amongst forces like, atmosphere-ionosphere-magnetosphere coupling through currents, energetic particles, electric fields and atmospheric drag. High latitude ionosphere shows featuring activities like, polar wind, evolution of cross tail potential difference, $E \times B$ drift of electron *etc.* Likewise mid-latitude ionosphere is characterised by special activities like meridional wind-forcing, plasma flow along geomagnetic field lines, generation of ring current and red arc. At low latitude plasma flow from one hemisphere to the other hemisphere of the earth along geomagnetic field lines is an interesting feature and equatorial fountain is also another feature worth observing. There are reports too of observation and analysis of effects in general of tides, gravity waves, geomagnetic field, sunspot group cycle, ionospheric storms, small scale structure *etc.* on ionospheric activities at different latitudes.

Like Davis and Smith [1], Chandra *et al* [2] too observed that the peak of OI 6300 Å occurs at about ±15° geomagnetic latitude and peak for the northern hemisphere is greater than the peak for the southern hemisphere.

Duncan [8] observed that electron density variation is approximately symmetric in periodicity against geomagnetic latitude which is observed also from Davis and Smith-curve and Wu and Newill-electron density profile (Figure 1). Similar variation has also been observed in observed and theoretically matched OI 6300 Å nightglow variations with latitude (Figure 1) having a period approximately of 32°.5.

Kimura *et al* [29] established their plasmaspheric DE (Diffusive Equilibrium) model, which they compared and checked with reference to SUPIM (Shefield University Plasmaspheric and Ionospheric Model) and gives electron concentration as a function of latitude. Their model shows that the electron density has an oscillatory nature of variation with respect to latitude which is similar to the case of ours. Miller *et al* [30] proved a semiempirical meridional wind model of neutral wind speed in upper thermosphere. Observations from our semiempirical curve-fitting formula along with the Davis-Smith latitude-variation curve can be explained partially with the help of Miller *et al*'s [30] model in the following way.

In northern hemisphere in general average wind speed decreases with latitude while in southern hemisphere increases with latitude. Increased wind speed causes cooling down of inosphere and thus lowering down the intensity of emission in general while decreased wind speed causes maintaining higher temperature and thus yields greater intensity of emission. Exactly this feature is exhibited by the continuous part *i.e.* $I_{6300 N\,O^*}(R) = 107.59 - 32.4\exp[0.014\lambda° - 0.14]$ and this non-oscillatory part has already been proposed to be attributed to the global wind speed mode of variation. At higher latitude sector *i.e.* for latitude greater than 30° on either side of the globe, the wind speed is supposed to exhibit opposite mode of variation with latitude compared to the mode at low latitude sector. The 10.7 cm solar flux influence, on the other hand affects only at higher latitude sector and balances this opposite mode of variation. Thus the variation of OI 6300 Å intensity is continuously increasing in northern and is decreasing in southern hemisphere as can be observed from Figure 1 Zalesak [31] mentions about some of the small scale structures mentioned earlier among which the formation and buoyant rise of low density bubbles of plasma in the nighttime equatorial ionosphere as equatorial spread F(ESF) driven by the collisional Rayleigh-Taylor instability has a bearing with magnetic field intensity and, hence it is also latitude dependent Sobral *et al* [32] made their precise observation of major importance in the south to north travelling airglow valley (SNE) and their observation indicates that the airglow minima and their travelling in south to north direction are partially caused by gravity waves modulation of airglow intensity Even after this gravitational perturbation the characteristic features of airglow variation with latitude shows consistency with Davis-Smith-curve (Figure 1).

Field and Rishbeth [33] has studied the response of F_2-layer to geomagnetic influences through a parameter $\mathrm{Ln}(N_mF_2^*/N_mF_2)$ which is the natural logarithm of the ratios of disturbed peak electron density ($N_mF_2^*$) to the quiet peak electron density (N_mF_2) and this parameter is expressed by them as a function of local time as below :

$$\mathrm{Ln}\left|(N_mF_2^*)/(N_mF_2)\right| = \bar{N} + \tilde{N}f(t - \hat{t}),$$

where $\bar{N}$ is termed as the DC component and $\tilde{N}$ as the AC component while $\hat{t}$ is local time for the maximum. From graphical plot of N *versus* geomagnetic latitude presented by Field and Rishbeth it can be observed that $N_mF_2^*$ value is much less than N_mF_2 value in higher latitude while $N_mF_2^*$ value is higher than N_mF_2 value in low latitude sector. The most probable cause of this type of latitude-anomaly may be due to stronger coupling of geomagnetically consequenced ionospheric storms with axial rotation of earth at high latitude than at low latitude. Field and Rishbeth [33] considers the following equation established from the theory of F-region photochemistry

$$\mathrm{Ln}\left|(N_m F_2^*)/(N_m F_2)\right| = \mathrm{Ln}\left|[\mathrm{O}/\mathrm{N}_2]^*/[\mathrm{O}/\mathrm{N}_2]\right|$$

and explains that [O/N_2] at F-region is much reduced at high latitude but remains more or less constant at low latitudes. Observations of Field and Rishbeth were made within the 19th solar cycle within which the observations of Davis and Smith on latitude variation of OI 6300 Å nightglow intensity and of Wu and Newil on the latitude variation of electron density (Figure 1) both were made too. From the work of Field and Rishbeth, it is also observed that seasonal change has almost no effect on the longitudinal pattern of latitudinal variation and the latitudinal variation observed there from may be caused by solar thermal ionising radiation input which has practically some anomaly over longitudinal distribution due to natural inclination of earth's axis to its plane of orbital rotation.

Mukherjee [34] finds out that for intense magnetic disturbances the airglow fluctuations are mainly controlled by sharp changes in variation of h'F. The period of airglow variation generally corresponds to periods of F-region height variation during magnetic disturbances. This may affect Barbier-equation modelled values of OI 6300 Å nightglow intensity variation (Figures 2 and 3).

4. Conclusion

From the analysis and discussion made in the preceding section the following conclusions can be drawn :

(i) The two distinct modes of latitudinal variation of oxygen red line nightglow intensity, the non-oscillatory or steady (DC Component) and the oscillatory (AC Component) have been expressed in precise mathematical form.

(ii) The oscillatory mode of variation with latitude was interpreted in terms of the influence of rotation of earth and angle of inclianation of its axis on solar terrestrial relationship through different characteristic solar parameters and geomagnetic field intensity distribution against latitude along with its associated phenomena by Davis and Smith themselves [1]. But the non-oscillatory mode of variation with latitude has been explained in this paper with the help of different models, associated with wind speed distribution and tidal and gravitational disturbances.

(iii) OI 6300 Å nightglow emission is mostly electron density dependent although at higher latitude some anomaly can be observed. Activating and deactivating or quenching species are involved in producing OI 6300 Å emission line *via* electron and hence electron density is certainly the principal factor for OI 6300 Å emission intensity variations. Perturbative effects may occur due to small scale irregularities in the ionosphere.

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